PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Statistical Support For Salmonid Survival Studies

BPA project number: 8910700
Contract renewal date (mm/yyyy): 12/1999 ☐ **Multiple actions?**

Business name of agency, institution or organization requesting funding
University of Washington

Business acronym (if appropriate) UW

Proposal contact person or principal investigator:

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NPPC Program Measure Number(s) which this project addresses
NPPC Doc 94-55: 3.2, 3.2F, 4.3B, 4.3C.1, 5.0F, 5.2A.7

FWS/NMFS Biological Opinion Number(s) which this project addresses
NMFS 1995 Hydrosystem Operations BO: RPA 13, Develop comprehensive monitoring, evaluation and reseach program; RPA 13f, Evaluate juvenile survival during downstream migration; RPA 17, Test hypotheses underlying life cycle models.

Other planning document references
NMFS 1995 Proposed Recovery Plan for Snake River Salmon: 0.3.b, Regional capabilities for biological analysis and modeling; 1.5.a, Determine effects of water withdrawals on salmon survival; 2.1.d.3, Evaluate juvenile survival during downstream migration; 2.1.d.5, Comprehensive monitoring, evaluation and research program; 2.1.d.1, Test the effects of increased spill on juvenile salmon survival; 2.6.c.3, Investigate survival rates for adult salmonids migrating upriver.

Short description
Improve monitoring and evaluation capabilities by developing better measurement tools and study designs to estimate juvenile and adult survival. Develop statistical methods to determine salmonid survival rates and survival relationships.

Target species
Chinook salmon and steelhead

Section 2. Sorting and evaluation

Subbasin
Systemwide

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type
Mark one or more caucus	If your project fits either of these processes, mark one or both	Mark one or more categories
☒ Anadromous fish ☐ Resident fish ☐ Wildlife	☐ Multi-year (milestone-based evaluation) ☐ Watershed project evaluation	☐ Watershed councils/model watersheds ☒ Information dissemination ☐ Operation & maintenance ☐ New construction ☒ Research & monitoring ☒ Implementation & management ☐ Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
8712700	Smolt Monitoring by Non-Federal Entities [PSMFC]	Complementary, provides technical assistance and technology transfer of statistical software to assist survival analyses.
8910800	Monitoring and Evaluation Modeling Support [UW]	Complementary, maintains and upgrades statistical software, theory and methods for investigating juvenile and adult salmon and steelhead survival rates and

		relationships.
9008000	Columbia Basin PIT-Tag Information System [PSMFC]	Dependent, project requires high quality PIT-tag data made available through Project 90-080-00 PTAGIS database to extract PIT-tag information to analyze survival data in various formats.
9102900	Supplementation and Survival of Fall Chinook in the Snake River [USFWS]	Complementrary, provides analytical and statistical models and computer software (e.g., SURPH) for survival estimation.
9105100	Monitoring and Evalution Statistical Support for Life-Cycle Studies [UW]	Complementary, maintains and upgrades statistical software, theory and methods for investigating juvenile and adult salmon and steelhead survival rates and relationships.
9302900	Survival Estimation for Dam/Reservoir Passage [NMFS]	Complementary, provides analytical and statistical support to respond to NMFS requests to enhance survival estimation capabilities incorporated in Program SURPH. Responds to requests to NMFS to investigate alternative analyses.
9303701	Technical Assistance with Life Cycle Modeling [PER Ltd.]	Complementary, maintains and upgrades statistical software, theory and methods for investigating juvenile and adult salmon and steelhead survival rates and relationships.
9503400	EW Program Support [BPA]	Critical to development of improved analystical tools and consistency in survival estimation across all salmon life cycle stages to maximize learning and the ability to evaluate the success of implemented actions and identify future mitigation options.
9600600	PATH Facilitation, Technical Assistance, & Peer Review [ESSA]	Complementary, maintains and upgrades statistical software, theory and methods for investigating juvenile and adult salmon and steelhead survival rates and relationships.
9600800	PATH - Participation by State & Tribal Agencies [ODFW]	Complementary, maintains and upgrades statistical software, theory

		and methods for investigating juvenile and adult salmon and steelhead survival rates and relationships.
9600801	Provide Scientific Input to PATH Process [NMFS]	Complementary, maintains and upgrades statistical software, theory and methods for investigating juvenile and adult salmon and steelhead survival rates and relationships.
9601700	Provide Technical Support in PATH [BA Inc.]	Complementary, maintains and upgrades statistical software, theory and methods for investigating juvenile and adult salmon and steelhead survival rates and relationships.
9700200	PATH-UW Technical Support	Complementary, maintains and upgrades statistical software, theory and methods for investigating juvenile and adult salmon and steelhead survival rates and relationships.
9800100	Analytical Support - PATH and ESA Biological Assessments [HES]	Complementary, maintains and upgrades statistical software, theory and methods for investigating juvenile and adult salmon and steelhead survival rates and relationships.

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?
1989	Developed theory to assess survival effects that results from ambient river conditions.	Improved analytical capabilities to conduct research on survival processes of wild and hatchery chinook and steelhead during smolt outmigration.
1990	Began software development for statistical analyses, and began statistical theory to assess individual covariate effects on survival.	Improved analytical capabilities to conduct research on survival processes of wild and hatchery chinook and steelhead during smolt outmigration.
1991	Demonstrated ability to simultaneously assess ambient effects and individual	Improved analytical capabilities to conduct research on survival

	covariate effects.	processes of wild and hatchery chinook and steelhead during smolt outmigration.
1992	Extended computer software to include analysis of group and individual covariate effects. Proposed "strawman" design for development of PIT-tag facilities on Snake/Columbia River. Developed study plan for a Snake River survival study evaluation.	Improved analytical capabilities to conduct research on survival processes of wild and hatchery chinook and steelhead during smolt outmigration.
1993	Completed statistical software development of analysis package--final debugging of computer program, helped facilitate Snake River survival study, and conducted analysis of hatchery survival studies.	Improved analytical capabilities to conduct research on survival processes of wild and hatchery chinook and steelhead during smolt outmigration.
1994	Completed SURPH statistical software and dissemination of a users manual for statistical analysis of data. Continued to support NMFS survival studies.	Continued to refine and expand statistical methods and software applications to meet the needs of NMFS and other users, and provide consistency in the application of methodologies for survival estimation across all life cycle stages.
1995	Produced a PC version of SURPH software and sample size program to design tag-release studies. Continued to support NMFS survival studies.	Continued to refine and expand statistical methods and software applications to meet the needs of NMFS and other users, and provide consistency in the application of methodologies for survival estimation across all life cycle stages.
1996	Developed statistical methods for estimating season-wide survival. Developed proper statistical model to estimate survival rates for fall chinook with residualization . Continued to support NMFS survival studies.	Continued to refine and expand statistical methods and software applications to meet the needs of NMFS and other users, and provide consistency in the application of methodologies for survival estimation across all life cycle stages.
1997	Improved statistical models and software for expanded survival experiments. Continued to support survival studies. Investigate alternative approaches to ocean survival rates. Assisted Nez Perce tribe in performing survival analyses.	Continued to refine and expand statistical methods and software applications to meet the needs of NMFS and other users, and provide consistency in the application of methodologies for survival

		estimation across all life cycle stages.
1998	Developed batch analysis programs for NMFS to permit the statistical analysis of very large data sets. Developed new unified (PC and UNIX) version of SURPH with greater model specification abilities needed for paired- release investigations.	Continued to refine and expand statistical methods and software applications to meet the needs of NMFS and other users, and provide consistency in the application of methodologies for survival estimation across all life cycle stages.
1998	Completed statistical theory for longitudinal analysis of time-varying, individual-based covariates in survival analyses.	Continued to refine and expand statistical methods and software applications to meet the needs of NMFS and other users, and provide consistency in the application of methodologies for survival estimation across all life cycle stages.
1998	Demonstrated feasibility of extracting precise and detailed information on smolt survival and passage rates at hydroprojects using radiotelemetry models.	Continued to refine and expand statistical methods and software applications to meet the needs of NMFS and other users, and provide consistency in the application of methodologies for survival estimation across all life cycle stages.

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Maintenance of SURPH.1 software	a	Maintain SURPH software.
		b	Maintain internet access to SURPH software.
		c	Alter SURPH software as required to work on changing computer systems and platforms.
		d	Respond to user questions and provide users with manuals and individual instruction.
2	Improve SURPH statistical software	a	Implement new time-varying covariate analyses.
		b	Implement goodness-of-fit and tests of model assumptions.
3	Develop generalized survival	a	Develop interactive programming to

	modeling for radiotelemetry investigations		allow user-specified model development for radiotelemetry survival analyses.
		b	Develop guidelines for radiotelemetry survival analyses and software to identify misspecified and valid models.

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	12/1999	11/2000	RPA 13		25.00%
2	12/1999	11/2000	RPA 13		45.00%
3	12/1999	11/2000	RPA 13f		30.00%
					0.00%
				Total	100.00%

Schedule constraints
Changes in the marking programs could impact survival research and scheduled analyses of these tagging studies to determine survival relationships.

Completion date
Ongoing indefinitely to support Columbia River Basin survival studies.

Section 5. Budget

FY99 project budget (BPA obligated): $183,300

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel		%52	96,040
Fringe benefits		%12	22,750
Supplies, materials, non-expendable property	Includes computer upgrades, software, licenses, services, etc.	%10	17,900
Operations & maintenance	O&M occur across a number of budget items. For FY2000, 41% of total budget = $75,821	%0	
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		%0	
NEPA costs		%0	
Construction-related		%0	

support			
PIT tags	# of tags:	%0	
Travel		%2	3,000
Indirect costs	26% of the total direct costs less costs for equipment, graduate operating fee, and office lease	%19	35,100
Subcontractor		%0	
Other	Office lease	%5	10,140
TOTAL BPA FY2000 BUDGET REQUEST			$184,930

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
		%0	
		%0	
		%0	
		%0	
Total project cost (including BPA portion)			$184,930

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	$187,000	$193,000	$195,000	$201,000

Section 6. References

Watershed?	Reference
☐	Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, and K. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. Amer. Fish. Soc. Monograph No. 5.
☐	Clobert, J., J. D. Lebreton, and D. Allaine. 1987. A general approach to survival rate estimation by captures or resightings of marked birds. Ardea 75: 133-142.
☐	Clobert, J., J. D. Lebreton, M. Clobert-Gille, and H. Coquillart. 1985. The estimation of survival in bird populations by recapture or resighting of marked individuals. In Statistics in Ornithology, B. J. T. Morgan and P. M. North (Eds.) pp. 197-213.
☐	Cormack, R. M. 1964. Estimates of survival from the sighting of marked animals. Biometrika 51: 429-438.
☐	Diggle, P. J., K. Liang, and S. L. Zeger. 1996. Analysis of longitudinal data. Oxford Univ. Press. Oxford, UK. 253 pp.
☐	Jolly, G. M., 1965. Explicit estimates from capture-recapture data with both

	death and immigration—stochastic model. Biometrika 52: 225-247.
☐	Hoffmann, A. 1993. Quantifying selection in wild populations using known-fate and mark-recapture designs. Ph.D. dissertation. Univ. of Washington, Seattle, WA.
☐	Hoffmann, A., and J. R. Skalski. 1995. Inferential properties of an individual-based survival model using release-recapture data: Sample size, validity and power. J. Appl. Stat. 22: 579-595.
☐	Lowther, A. B. 1998. Development, expansion, and evaluation of release-recapture survival models for Snake River juvenile salmonids, with new algorithms allowing time-dependent individual covariates. Ph.D. dissertation. Univ. of Washington.
☐	Lowther, A. B., and J. R. Skalski. 1998a. A multinomial likelihood model for estimating survival probabilities and overwintering for fall chinook salmon using release-recapture methods. J. Agri. Biol. and Envir. Stat. 3:223-236.
☐	Lowther, A. B., and J. R. Skalski. 1998b. Monte-Carlo comparison of confidence interval procedures for estimating survival in a release-recapture study, with applications to Snake River salmonids. Bonneville Power Administration. Volume VII.
☐	Seber, G. A. F. 1965. A note on the multiple recapture census. Biometrika 52: 249-259.
☐	Skalski, J. R. 1998. Estimating season-wide survival rates of outmigrating smolt in the Snake River, Washington. Can. J. Fish. Aquat. Sci. 55:761-769.
☐	Skalski, J. R., A. Hoffmann, and S. G. Smith. 1993. Testing the significance of individual- and cohort-level covariates in animal survival studies. In: Marked Individuals in the Study of Bird Populations, EURING 92, pp. 9-28.
☐	Skalski, J. R., and J. A. Perez-Comas. 1998. Using PIT-tag recapture probabilities to estimate project-wide fish guidance efficiency and spill effectiveness at Lower Granite Dam. Army Corps of Engineers, Walla Walla District, Walla Walla, WA.
☐	Skalski, J. R., R. L. Townsend, J. R. Stevenson, and A. E. Giorgi. 1998. Recommendations on the design and analysis of radiotelemetry studies of salmonid smolts to estimate survival and passage efficiencies. Volume XI. Bonneville Power Administration.
☐	Smith, S. G. 1991. Assessing hazards in wild populations using auxiliary variables in tag-release models. Ph.D. dissertation. University of Washington, Seattle, WA.

PART II - NARRATIVE

Section 7. Abstract

Project 8910700 was initiated in 1989 to improve monitoring and evaluation capabilities of the Columbia River Fish and Wildlife Program (FWP) by developing

better measurement tools and study designs to evaluate relationships between ambient environmental conditions and the survival of juvenile and adult salmonids. The 1994 FWP states that the relationship between spring and summer flow, velocity, and fish survival should receive highest priority in the region's research efforts. Throughout its history, this project has provided statistical support and guidance on the design and analysis of PIT-tag survival studies to the Northwest fisheries community. This project is now also providing regional support for radiotelemetry survival studies in an effort to reduce sample sizes of ESA stocks and provide detailed survival and passage data.

Estimators of smolt and adult salmon survival rates are developed using maximum likelihood methods and generalized least-squares regression models based on release-recapture theory. Tests of survival hypotheses and estimation of survival relationships are based on state-of-the-art statistical analyses devised specifically to assess relationships within capture data. Statistical software (e.g., SURPH.1) is developed and distributed to support ongoing survival investigations.

The ultimate outcome of increased passage survival through the FCRPS depends upon the effectiveness of these survival measures to monitor migration success, investigate river management decisions, and to provide baseline information to evaluate future mitigation options. This project is anticipated to continue in some form beyond 2002 as part of the adaptive management monitoring and evaluation framework of the FWP.

Monitoring and evaluation of products comes from annual post-season evaluations performed by the contractor, direct users of the products, e.g., NMFS, PATH and other regional entities, and independent scientific peer reviews.

Section 8. Project description

a. Technical and/or scientific background

The Columbia River Basin Fish and Wildlife Program states that the relationship between spring and summer flow, velocity and fish survival should receive highest priority in the region's research efforts. This project was initiated in 1989 to develop the statistical theory and methods needed to analyze smolt and adult PIT-tag survival studies. This study conducted the initial feasibility studies to determine the applicability of using release-recapture theory (Cormack 1964) in conjunction with proposed PIT-tag detection and diversion systems to estimate smolt survival (Dauble et al. 1993). The feasibility studies resulted in sampling protocol used in the initial study designs for the National Marine Fisheries Service/University of Washington (NMFS/UW) Snake River survival studies of 1993-present (Project 9302900).

Because the Fish and Wildlife Program (4.3C.1), the Biological Opinion (13f), and the Recovery Plan for the Snake River (2.1.d.2, 2.1.d.3, 2.2.d.1, 2.6.c.3) call for the need to investigate juvenile and adult survival relationships to river operations and conditions, this project proceeded to develop statistical methods to assess survival effects based on first principle. Until recently (Clobert et al. 1985, 1987), only inefficient two-stage analyses that ignore the distribution nature of tagging data were available to investigators. This project developed statistically valid tests of survival effects (Skalski et al. 1993) using both group-wise and individual-based covariates. This theory led to the

development of the software program SURPH.1 available on UNIX and PC platforms. The resulting statistical methods provided valid and more powerful means of assessing survival relationships from tag data. This software and its subsequent developments have been used by NMFS since 1993 to analyze Columbia/Snake River survival studies (Skalski et al. 1998).

As the capabilities to conduct PIT-tag survival studies have expanded, so have the research questions and the subsequent need for statistical methods tailored to the investigations. This project has developed methods to validly analyze fall chinook smolt outmigration over two spring seasons (Lowther and Skalski 1998a), provide season-wide survival estimates (Skalski 1998), provide profile interval estimates of survival (Lowther and Skalski 1998b), and analyze time-varying covariates resulting from the capture-measure-recapture-remeasure of smolt during outmigration. This project continues to respond to user needs for software and statistical assistance in analyzing tagging studies. The software is now used nationally and internationally to assess survival relationships and natural selection.

As more stocks have become listed as threatened or endangered, the ability to tag thousands of smolt has declined. To this end, the project is also looking at the statistical ability of radiotelemetry studies to provide accurate and reliable survival information to fisheries managers. Technology transfer of radiotelemetry survival methods to John Day Dam drawdown studies, Bonneville Dam outfall studies, and Mid-Columbia survival studies will be performed in 1999.

b. Rationale and significance to Regional Programs

The Northwest's ability to conduct effective and meaningful PIT-tag studies from the onset was a consequence of integrating the programmatic and biological needs with electronics, logistics of PIT-tag facility placement, and statistical design and analyses. The capabilities and limitations of performing PIT-tag studies was known prior to implementation of large tag releases. As a consequence, efficient and worthwhile studies were prepared from the onset in a cost-effective and scientifically deliberate manner. This history contrasts sharply with the implementation of the coded-wire tag (CWT) methodology in the Northwest where expectations were high but study performance was nearly always below expectations. The statistical community (see literature for the Statistical Support Group, International Pacific Salmon Commission) has strived for a decade to find proper ways to analyze CWT studies.

The project serves as a vanguard in the development of regional capabilities to perform efficient and cost-effective tagging studies providing timely information to resource managers. Studies such as the Snake River survival studies (Project 9302900) performed by NMFS is a direct consequence of this original program.

Today, the project continues to serve its mission by tailoring the statistical methods of survival estimation and regression analyses to evolving regional research issues. The project is providing guidance on the design and analysis of the complex capture histories of fall chinook salmon smolt studies, the implementation of adult detection facilities, taking advantage of the recapture-remeasurement of smolt at downriver detection facilities and the broader issues of multiple-release analyses to estimate season-wide survival and the evaluation of survival effects. Current

investigations are analyzing up to 100-200 separate releases simultaneously to extract survival and capture relationships (Skalski and Perez-Comas1998).

In a similar manner, this project is helping regional investigators extract greater information on route-specific survival rates and passage efficiencies from radiotelemetry studies. With one technical report (Skalski et al. 1998), smolt radiotag studies have been transformed from descriptive investigations of fish movements to detailed studies of smolt survival and passage at hydroprojects. The project will provide technical assistance to assure these studies are designed to provide the greatest information with the least impacts on fiscal and fisheries resources.

c. Relationships to other projects

This project provides direct support to the NMFS/UW Snake River survival studies (Project 9302900). This project assures the statistical methods and computational capabilities will be available to meet all of the NMFS analytical needs now and into the future. Statistical methods are expanded and tailored to meet the changing requirements for the design and analysis of the studies as the community needs for information grow and evolve. These same capabilities for the design and analysis of tagging studies are also made available to other Northwest agencies and tribes needing assistance in conducting survival investigations.

In 1997, these statistical capabilities were transferred to the Army Corps of Engineers (ACOE) AFEP research program to analyze PIT-tag data to provide information on spill effectiveness (SE), fish guidance efficiency (FGE), and other operational effects. In 1998, these technologies will be transferred to the Mid-Columbia where reach survival studies will be initiated for the first time since the early 1980s. In 1999, the capabilities to conduct scientific radiotelemetry investigations of smolt survival will be transferred to 5-6 investigations at Mid- and Mainstem Columbia River hydroprojects.

d. Project history (for ongoing projects)

Project 8910700 was initiated in 1989 to develop the statistical theory and methods needed to analyze smolt and adult PIT-tag survival studies. The project developed the initial study designs for the National Marie Fisheries Service (NMFS/University of Washington (UW) Snake river survival studies of 1993-present (e.g. NMFS Project 302900) . These ongoing efforts have produced statistical software (i.e., SURPH) for UNIX- and PC-based computers which are accessible to the Columbia Basin community via internet and the World Wide Web (WWW). Additional products include a comprehensive users manual for SURPH and software for sample size calculations. As the Snake River survival studies have evolved, the numerical needs for new and more descriptive data analyses have also increased. This project continues to maintain existing analysis capabilities as well as add new data analysis features at program users' (e.g., NMFS) request. As the new 134.2 kHz frequency PIT tag decoder systems come on-line, the survival studies will be extended to the joint analysis of survival of both downriver smolts and returning adults. The project has already developed some of the key statistical software to analyze these data. Survival applications

have now been extended into the Mid-Columbia with PIT-tag and radiotag survival studies and the mainstem Columbia to assess mitigation projects at Bonneville and John Day Dam drawdowns. The project stands ready to assist all investigators interested in performing scientifically rigorous salmonid survival investigations.

Specific accomplishments by year include:

1989: Developed theory to assess survival effects that result from ambient river conditions.

1990: Began software development for statistical analyses, and began statistical theory to assess individual covariate effects on survival.

1991: Demonstrated ability to simultaneously assess ambient effects and individual covariate effects.

1992: Extended computer software to include analysis of group and individual covariate effects. Proposed "strawman" design for development of PIT-tag facilities on Snake/Columbia River. Developed study plan for a Snake River survival study evaluation.

1993: Completed statistical software development of analysis package--final debugging of computer program, helped facilitate Snake River survival study, and conducted analysis of hatchery survival studies.

1994: Completed SURPH statistical software and dissemination of a users manual for statistical analysis of data. Continued to support NMFS survival studies.

1995: Produced a PC version of SURPH software and sample size program to design tag-release studies. Continued to support NMFS survival studies.

1996: Evaluated proper approaches for estimating confidence intervals in release-recapture survival studies. Developed proper statistical model to estimate survival rates of fall chinook smolt taking into account residualization. Developed statistical methods for estimating season-wide survival. Continued to support NMFS survival studies.

1997: Developed statistical model to estimate ocean survival rates from CWT data. Developed model for time-varying (updated) covariates; to extract effects of smolt condition on in-river survival. Assisted Nez Perce tribe in performing survival analyses.

1998: Develop batch analysis programs for NMFS to permit the statistical analysis of very large data sets. Developed alpha-level new unified (PC and UNIX) version of SURPH with greater model specification capabilities needed for paired-release investigations performed by NMFS in the Mid-Columbia. Completed statistical theory for longitudinal analysis of time-varying, individual-based covariates in survival analysis.

Demonstrated feasibility of extracting precise and detailed information on smolt survival and passage rates at hydroprojects using radiotelemetry models.

In conjunction with NMFS, this study has helped to generate new biological understandings of the dynamics of smolt outmigration. These findings include:
1. Information on smolt travel time - survival relationships.
2. Information on river flow/temperature - survival relationships.
3. Comparisons of hatchery and wild chinook and steelhead smolt survival.
4. Comparison of smolt survival across 5 years and 2-4 river reaches.
5. Survival rates of upper Snake River hatchery releases.
6. Baseline survival data for comparison with potential mitigation practices in years to come.

BPA Contract Reports:

DOE/BP-02341-1: Skalski, J. R., A. Hoffman, and S. G. Smith. 1993. Development of Survival Relationships Using Concomitant Variables Measured from Individual Smolt Implanted with PIT-tags. 1990-1992 Annual Report prepared for Bonneville Power Administration, Portland, Oregon.

DOE/BP-02341-2: Smith, S. G., and J. R. Skalski. 1994. SURPH.1 Manual: Statistical Survival Analysis of Fish and Wildlife Tagging Studies. Computer Software Manual prepared for Bonneville Power Administration, Portland, Oregon.

DOE/BP-02341-3: Center for Quantitative Science, School of Fisheries, University of Washington. 1996. Introduction to SURPH.1 Analysis of Release-Recapture Data for Survival Studies. Technical Report prepared for Bonneville Power Administration, Portland, Oregon.

DOE/BP-02341-4. Westhagen, P, and J. R. Skalski. 1998. Instructional Guide to Using Program CaptHist to Create SURPH Files for Survival Analysis Using PTAGIS Data Files. Volume X in the BPA Technical Report Series, the Design and Analysis of Salmonid Tagging Studies in the Columbia Basin Bonneville Power Administration, Portland, Oregon.

DOE/BP-02341-5: Lowther, A. B., and J. R. Skalski. 1998. Monte-Carlo comparison of confidence interval procedures for estimating survival in a release-recapture study, with applications to Snake River salmonids. Volume VII in the BPA Technical Report Series, the Design and Analysis of Salmonid Tagging Studies in the Columbia Basin Bonneville Power Administration, Portland, Oregon.

DOE/BP-02341-6: Lowther, A. B., and J. R. Skalski. 1998. A Model for Estimating Survival Probabilities and Residualization from a Release-Recapture Study of Fall Chinook (*Oncorhynchus tschawytscha*) Smolts in the Snake River. Volume VIII in the BPA Technical Report Series, the Design and Analysis of Salmonid Tagging Studies in the Columbia Basin Bonneville Power Administration, Portland, Oregon.

DOE/BP-35885-11: Newman, K. 1998. Estimating Salmonid Survival with Combined PIT-CWT Tagging. 1998. Volume II in the BPA Technical Report Series, the Design and Analysis of Salmonid Tagging Studies in the Columbia Basin. Bonneville Power Administration, Portland, Oregon.

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DOE/BP (in press): Skalski, J. R., J. A. Perez-Comas, P. Westhagen, and S. G. Smith. Assessment of Temporal Trends in Daily Survival Estimates of Spring Chinook, 1994-1996. Volume I in the BPA Technical Report Series, the Design and Analysis of Salmonid Tagging Studies in the Columbia Basin Bonneville Power Administration, Portland, Oregon.

DOE/BP (in press): Skalski, J. R., R. L. Townsend, A. E. Giorgi, and J. R. Stevenson. 1998. Recommendations on the Design and Analysis of Radiotelemetry Studies of Salmonid Smolts to Estimate Survival and Passage Efficiencies. Volume XI in the BPA Technical Report Series, the Design and Analysis of Salmonid Tagging Studies in the Columbia Basin Bonneville Power Administration, Portland, Oregon.

Dissertations:

Smith, S. G. 1991. Assessing hazards in wild populations using auxiliary variables in tag-release models. Ph.D. dissertation. Univ. of Washington. Seattle, WA.

Hoffmann, A. 1993. Quantifying selection in wild populations using known-fate and mark-recapture designs. Ph.D. dissertation. Univ. of Washington. Seattle, WA.

Lowther, A. B. 1998. Development, expansion, and evaluation of release-recapture survival models for Snake River juvenile salmonids, with new algorithms allowing time-dependent individual covariates. Ph.D. dissertation. Univ. of Washington. Seattle, WA.

Other Scientific Reports Produced for Publication:

Skalski, J. R., A. Hoffmann, and S. G. Smith. 1993. Testing the significance of Individual-and cohort-level covariates in animal survival studies. EURING 92. In:

Marked Individuals in the study of bird populations, edited by S.D. Lebreton and P.M. North, pp.9-28. Birkhauser Verlag. Boston, MA.

Skalski, J. R., and S. G. Smith. 1994. Risk assessment in avian toxicology using experimental and epidemiological approaches. In: Wildlife toxicology and population modelling: Integrated studies of agroecosystems, pp.467-488. Lewis Publishers. Boca Raton, FL.

Hoffmann, A., and J. R. Skalski. 1995. Inferential properties of an individual-based survival model using release-recapture data: Sample size, validity and power. J. Appl. Stat. 22:579-595.

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Other Related Joint Contributions:

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Adaptive Management Implications

Both the Northwest Power Planning Council's Fish and Wildlife Program and the National Marine Fisheries Service (NMFS) 1995 Hydrosystem Operations Biological Opinion call for implementation of reliable monitoring and evaluation of mitigation actions within the Columbia River Basin in support of an adopted adaptive management framework. With respect to evaluating actions associated with hydropower operations, three performance measures have been repeatedly identified as being instructive; smolt mitigation speed, smolt survival through the hydroelectric complex, and subsequent survival to adulthood. Activities of this project strive to address these performance measures in an adaptive management framework by:

1. Assessing the accuracy and precision of such performance measures.
2. Identifying any deficiencies in estimation procedures.
3. Identification and/or development of analytical approaches to improve the statistical integrity of such estimates.
4. Examining the relationships between these performance measures and a variety of predictor variables that can affect salmon survival, particularly as associated with conditions encountered during their seaward migration.

This project promotes adaptive management by providing the statistical underpinnings to ongoing smolt survival studies being conducted by NMFS on the Snake/Columbia Rivers. Data generated by these studies are being used to monitor outmigration success, provide baseline information to evaluate future mitigation measures, update Columbia River models (i.e., CRiSP) and investigate river management decisions such as flow augmentation and spill programs.

Budget History

	Year	Annual Budget Obligated
Project Initiated	1989	$99,999
	1990	0,000
	1991	127,871
	1992	130,656
	1993	197,060
	1994	168,011
	1995	164,725
	1996	169,952
	1997	150,888
	1998	179,424

e. Proposal objectives

The overall goal of the project is to improve analytical capabilities to conduct research on survival processes of wild and hatchery chinook and steelhead during smolt outmigration. Further, this project stands ready to provide analytical support to estimate ocean survival and in-river survival of returning adults when adult detection facilities are in place. The resulting improved monitoring and evaluation capabilities will assist in-season river management by optimizing operational and fish passage strategies.

Specific objectives for the 2000 project year are as follows.

Objective 1. Maintain the SURPH.1 statistical software and provide user support.

Objective 2. Provide improvements in statistical theory and software as requested by user groups.

Objective 3. Develop valid user-specified statistical models to extract survival information from radiotelemetry fish tagging studies.

The statistical software program SURPH.1 developed at the UW to analyze PIT-tag survival studies is also maintained, debugged, and enhanced at the UW. Maintenance now includes upkeep of both UNIX and PC versions of the software and internet access. As computer systems routinely upgrade, the software must be altered to work on the newer systems and computer platforms. The other maintenance issues under Objective 1 include responding to user questions and providing users with software, manuals, and individual instruction.

During 2000, upgrades in statistical software will continue to enhance the SURPH program. Development of an interactive user-specified modeling program (Objective 3) will be developed whereby investigators tailor survival models to their unique

requirements. With PIT-tag investigations, detector arrays are defined by expensive fixed-location facilities at hydroprojects. However, antenna arrays used in radiotelemetry survival studies can be positioned in a limitless number of possible ways. Software to define and identify valid statistical models to estimate survival as well as fish guidance efficiency (FGE) and spill effectiveness (SE) will be developed from the radiotag studies.

Program SURPH will also be augmented to analyze longitudinal studies (Objective 2) to investigate relationships between survival and time-varying, individual-based covariates. The intent of both of these objectives is to extract greater information from tagging studies as the prospects of handling large numbers of ESA-listed stocks decreases. Results for 2000 will be presented in technical reports, peer-reviewed scientific publications, and free statisitcal shareware available through the internet.

f. Methods

State–of-the-art statistical methods for the analysis of PIT-tag release-recapture methods are being developed using first principles (Smith 1991, Hoffmann 1993, Lowther and Skalski 1998a, Skalski et al. 1993, Skalski 1998). The research began with standard estimation methods found in Cormack (1964), Jolly (1965), Seber (1965), and Burnham et al. (1987). These point-estimation techniques were then developed in a hypotheses testing framework to assess the effects of treatment effects and group-covariates on survival relationships (Smith 1991). The theory was then generalized to allow quantifying how physical traits of individual fish influence survival and capture probabilities to more realistically characterize survival processes of wild populations (Hoffmann 1993, Hoffmann and Skalski 1995). Valid testing procedures were developed (Skalski et al. 1993) to assure survival effects would be reliably and dependably assessed, using both cohort-based and individual-based covariates. Longitudinal analyses of time-varying covariates (Diggle et al. 1996) were extended to release-recapture data by Lowther (1998). He developed valid methods of assessing effects and constructing standard errors when covariates are repeatedly measured over time on the same individuals. These factors include changing morphology, conditions of the smolt, and their upstream passage history. Current efforts are extending these capabilities to the development of user-specified software and the ability to symbolically identify valid and faulty statistical models. The focus on valid statistical methods is to assure defensible analytical methods are used in order that the fisheries community and fisheries managers can concern themselves with the biological and resource management issues and not the uncertainties of the analyses.

g. Facilities and equipment

This project is supported by 6 SUN UNIX workstations, 1 X-terminal, and 3 personal computers. The computer system is also supported by a network computer system, allowing a dynamic amount of storage capacity to meet the project needs and a T1 communications line for ethernet access to the internet.

h. Budget

Personnel costs are consistent with previous years adjusted for promotions and Washington state wage adjustments of 3% for AY2000. Supplies include a PC workstation for $4,600; upgrades to software; computer maintenance; computer insurance; publication costs; phone services; copy services, internet access on T1 line, and mailing costs. Travel costs include multiple trips planned to Portland, Oregon, to consult with BPA sponsor and other fisheries offices located in Portland. Travel also includes one trip to a national meeting to present research results. Because research offices are located off-campus, indirect costs are 26% instead of 52% associated with on-campus projects but require additional costs for office lease, furniture, etc., but with substantial savings.

Section 9. Key personnel

John R. Skalski
Professor of Biological Statistics
School of Fisheries
University of Washington
FTE = 0.17

Dr. Skalski directs the project, guides staff and graduate student progress on research, provides statistical theory underlying the research developments, sets and monitors project milestones, and monitors budget. He also provides public presentation of results, authors peer-reviewed scientific publications, and consults with interested parties on the design and analysis of tagging studies. Dr. Skalski is the author of over 50 papers and books on fish and wildlife studies.

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EDUCATION

B.S.	Wildlife Management/Biology, University of Wisconsin, Stevens Point	1974
M.S.	Wildlife Science, Oregon State University	1976
M.S.	Biometry, Cornell University	1978
Ph.D.	Biometry, Cornell University	1985

EMPLOYMENT HISTORY

1978-1985	Research Scientist, Battelle Pacific Northwest Laboratory, Richland, WA
1985-1987	Senior Research Scientist, Battelle Marine Research Laboratory, Sequim, WA
1987-1995	Associate Professor, University of Washington, Center for Quantitative Science, School of Fisheries, Seattle, WA
1992-1995	Interim Director, Center for Quantitative Science in Forestry, Fisheries, and Wildlife, University of Washington
1994-1995	Chair, Interdisciplinary Graduate Program in Quantitative Ecology and Resource Management, University of Washington
1995-Present	Professor, University of Washington, School of Fisheries, Seattle, WA

CERTIFICATION

Certified Wildlife Biologist, 1982, The Wildlife Society.

EXPERIENCE

Dr. Skalski has 20 years of experience as a research scientist and professor of biological statistics. His expertise is in the statistical methods of parameter estimation, sampling theory, impact assessment, population dynamics, and mark-recapture theory. Of particular relevance is his experience and expertise in effects assessment on mobile species and the design and analysis of animal tagging studies. He has been chief statistician on accident assessments of major oil spills, design and analysis of impact assessment studies of major energy production facilities, hydroacoustic fish surveys, and fish tagging studies. He has worked on the design and analysis of Columbia River salmonid tagging studies for nine years.

SELECTED PUBLICATIONS

Lowther, A. B., and J. R. Skalski. 1998. A multinomial likelihood model for estimating survival probabilities and overwintering for fall chinook salmon using release-recapture methods. J. Agri. Biol. and Envir. Stat. 3:223-236.

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Section 10. Information/technology transfer

The primary product of this project is a technology transfer of information on the most appropriate, sensitive, and valid means of analyzing tagging data to extract survival information useful in management decision. The project also conveys information on the most effective and cost-efficient study designs for analyzing smolt and adult survival studies.

Information is disseminated by BPA technical reports, University dissertations, and scientific peer-reviewed literature. SURPH.1 software and user manuals are distributed upon request to all users, and the software and instructions can be downloaded through the internet (http://www.cqs/washington.edu/surph). In addition, users can perform their analysis through the internet site. Project personnel are also available to provide statistical support to any individual in the Northwest fisheries community upon request. Personnel respond to requests by telephone, mail, internet e-mail, and site visits, depending on user needs and preferences.

Congratulations!